BMT WBM

Our Ref: : L.B20176.004.docx

5 December 2013

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Attention: Paul Busmanis

Dear Paul

RE: WEST BALLINA FLOOD RELIEF OPTIMISATION STUDY

Following assessment of the impacts associated with the development of three parcels of land in West Ballina (ref. L.B20176.003.docx (BMT WBM, 12 July 2013)) and a subsequent meeting with the Ballina Highway Service Centre developers (ref. M_B20176_001_Meeting_Minutes_130819.doc (BMT WBM, 19 August 2013)), BMT WBM has been commissioned to undertake an 'optimisation study' relating to the implementation of mitigation works associated with the development. The mitigation works, referred to as the West Ballina Flood Relief, comprise a floodway from north to south through the development site to a set of culverts beneath River Street in West Ballina. Since the 1990's, these mitigation works have been included in Ballina Shire Council's flood mitigation scheme. The previous modelling work, undertaken to assess the impacts of the development, identified that two (2) of the ultimate 10 culvert cells would be sufficient to mitigate the impacts of the West Ballina development (Lot 1 DP238009). At a later stage, as the need arises, Council would then be able to upgrade the culverts to the ultimate configuration. Additional to the culverts under River Street, there will be a set of culverts across the upstream floodway to provide an access road to the proposed development. Refer to Figure 1 for locality and Figure 3 for schematic layout of culverts.

This letter report describes the outcomes from an 'optimisation study' for the West Ballina Flood Relief. The focus of the study has been the immediate mitigation works (i.e. two cell culverts or equivalent). However, consideration has also been given to the future expansion of the culverts.

For this study, a matrix of 42 scenarios has been developed to identify the design required to achieve optimum performance of the West Ballina Flood Relief. The following design aspects have been assessed:

- Culvert dimensions – the size and number of cells required to mitigate the impacts of the West Ballina developments
- Floodway invert and cross section
- The need for backflow prevention (such as a weir or floodgates) to prevent tidal inundation of the floodplain

For complete assessment, both local catchment and Richmond River dominated floods have been considered, as well as floods of different magnitudes (20 year and 100 year ARI).

The outcomes from the assessment are described below.

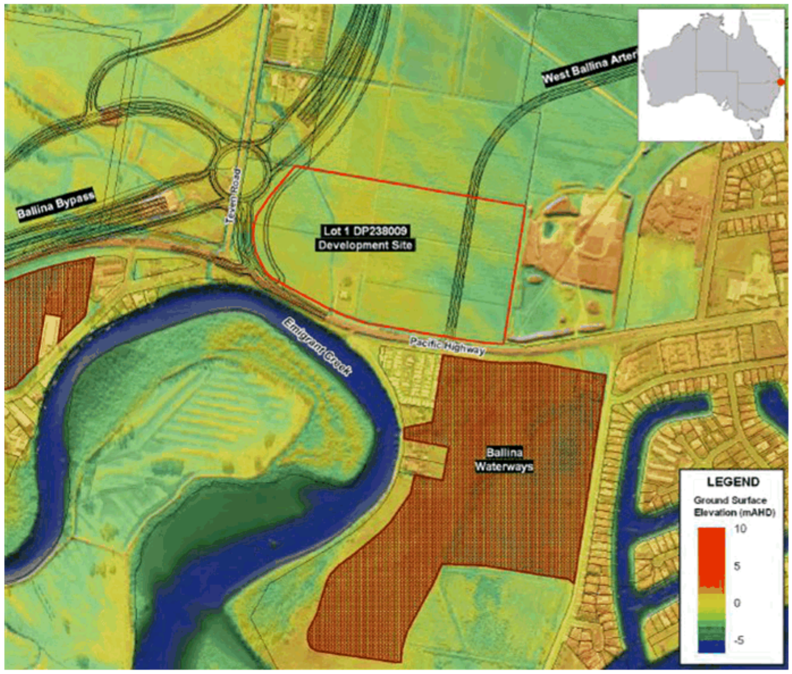

Figure 1 Lot 1 DP238009 development site and locality

Culvert Dimensions and Floodway Invert

To fit beneath the existing road embankment, culverts are set at 1.2m high. Culvert cell width has been set at 3.6m to minimise blockage potential. Due to site constraints (road level, tide levels and constructability) the culvert invert level has been set at 0m AHD as per previous reports. For this study, culverts configurations of 1, 2, 3, 4, 6, 8 and 10 cells have been modelled.

The floodway connecting the culverts to the floodplain has previously been modelled with invert levels of 0.65m and 1.0m AHD, base width of 40m and side slopes of 1:3. The natural ground levels along the floodway alignment are between 0.8m and 1.1m AHD. The floodplain at the northern end of the floodway is at approximately 0.6m AHD. For this study, floodway invert levels of 0.6m, 0.8m and 1.0m AHD have been modelled.

The matrix of simulations to assess the number of cells and the floodway invert level is presented in Table 1.

Table 1 Simulation matrix for culvert cells and floodway invert level

Number of cells	Floodway Invert Level (m AHD)		
	0.6m	**0.8m**	**1.0m**
1	100 year		100 year
2*	20 and 100 year	20 and 100 year	20 and 100 year
3	100 year		100 year
4	100 year		100 year
6	100 year		100 year
8	100 year		100 year
10*	20 and 100 year	20 and 100 year	20 and 100 year

* The Richmond River and local catchment dominated events have been modelled for the 2 and 10 cell culvert configurations

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Results of the assessment are presented in Figure 2 for the 100 year ARI local catchment event.

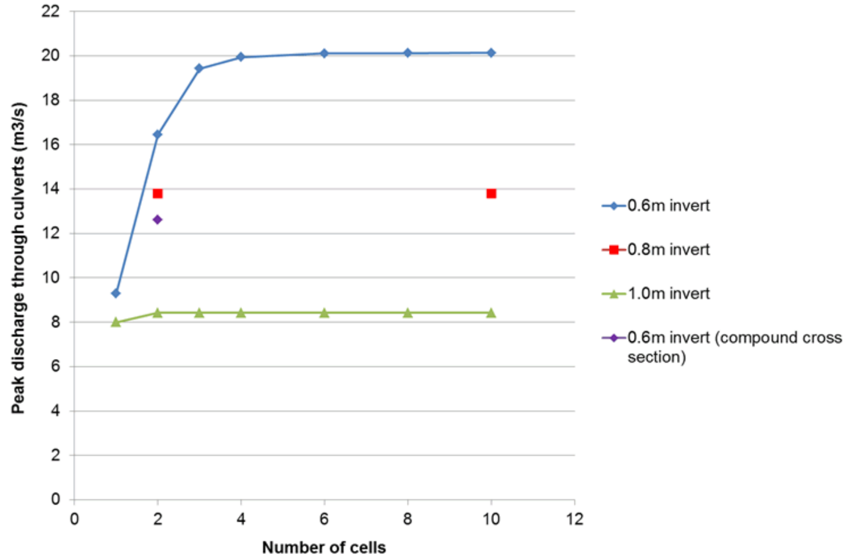

Figure 2 Peak discharge for various culvert cell and floodway invert combinations (100 year ARI local catchment event)

The results presented in Figure 2 indicate that for the 0.6m AHD floodway invert scenario, more than four culvert cells does not provide any significant improvement to peak discharge rates. The volumetric discharge is, however, greater with the larger number of cells due to high early discharge associated with wider culverts. This results in marginally lower peak flood levels and shorter inundation duration with more cells. The inundation duration has not been quantified as part of this optimisation study, however, will be undertaken as part of the future expansion of the culverts.

For a 1.0m AHD floodway invert, there is little difference in peak discharge rates above when more than 2 cells are used. Again, the volumetric discharge will be marginally greater with more than 2 cells.

Similar results are experienced during the Richmond River dominated floods and during the 20 year ARI event, although optimisation of the number of culverts was not undertaken (only 2 and 10 cells were modelled for events other than the 100 year ARI local catchment flood).

The reason for the minimal improvement above a certain number of cells is that the floodway becomes the hydraulic control (i.e. flow is restricted by the capacity of the floodway, not the culverts). The results of this assessment highlight the sensitivity of the floodway invert. By reducing the floodway invert from 1.0m to 0.6m AHD, the discharge through the West Ballina Flood Relief more than doubles. This is evident in all event sources (Richmond River and local catchment) and event magnitudes (20 year and 100 year ARI) that have been assessed.

Compound Cross Section

A compound cross section has also been assessed. The cross section assumed natural ground levels along the floodway, although cutting a 10m wide channel along the length to an invert level of 0.6m AHD. The peak discharge for a 2 cell configuration is shown on Figure 2. This shows that use of a low flow channel can significantly improve the floodway efficiency.

Need for Backflow Prevention

The need for floodgates or a weir to prevent tidal intrusion (backflow prevention) during high tides and to limit the back flooding of the floodplain during elevated Richmond River levels has been identified in the previous studies. The highest astronomical tide at Ballina is 1.1m AHD; this is projected to increase with sea level rise. Therefore, a mechanism to prevent water backing up the West Ballina Flood Relief is essential.

Three options have been considered as part of this assessment:

1. Floodgates on the outlet of the culverts;
2. Weir in the upstream channel, perpendicular to the centre line of the floodway; and
3. Weir in the upstream channel, 45 degrees to the centre line of the floodway.

The weir crest has been set at 1.2m AHD in the model simulations.

As expected, the use of floodgates provides the greatest efficiency. This is due to the ability for the floodway to operate at lower water levels. For the weir scenarios, the West Ballina Flood Relief will only operate when upstream flood levels exceed the height of the weir, in this case 1.2m AHD. At this stage, there would already be up to 0.6m of inundation across the floodplain.

Mitigating the Impacts of the West Ballina Development

As discussed in the previous assessment (ref. L.B20176.003.docx (BMT WBM, 12 July 2013)), a two cell arrangement provides sufficient flood mitigation to compensate for complete site filling. The previous modelling assumed a floodway invert of 0.65m AHD. The optimisation simulations have indicated adequate flood mitigation using a two cell arrangement and a 1.0m floodway invert (or natural ground level). This is valid for the 20 year and 100 year ARI events. Should the floodway also be lowered to 0.6m AHD, additional peak flood level reduction will occur.

Refer to Figure B20176-23 for peak flood level impacts associated with the recommended 2 cell culvert arrangement. Flood damages have been re-calculated for the undeveloped, unmitigated scenario and the developed, mitigated scenario. The analysis has shown an overall improvement is expected, with average annual damages reducing from $12,104,286 to $12, 065,151.

Summary

The following points summarise the outcomes from the optimisation study for the West Ballina Flood Relief (refer to Figure 3 for schematic layout and Table 2 for specification):

- Peak flood level impacts caused by complete site filling can be compensated using a two cell culvert arrangement for the River Street culverts (2 cells of 1.2m high by 3.6m wide), with an invert level of 0m AHD.
- Culverts for the internal access road should have a maximum invert level of 0.5m AHD to allow for future excavation of the floodway reserve. To minimise afflux associated with these culverts, the soffit should be above the 100 year ARI flood level (i.e. minimum of 2.0m AHD).
- A 40m wide floodway reserve at natural ground level must be maintained upstream from the access road culverts to connect with the floodplain to the north of the site.
- There is significant benefit in lowering the upstream floodway (from the access road culverts to the northern property boundary) to its ultimate design level of 0.6m AHD.
- A minimum 40m wide floodway must be provided between the River Street and access road culverts. The invert level of the floodway is to match the invert levels of the upstream and downstream culverts.
- A drop structure is required at the upstream face of the access road culverts. The form of the drop structure is preferred to be a batter with rock protection.
- Backflow prevention is required in the form of hinged floodgates fitted to the downstream side of the River Street culverts.

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Figure 3 Schematic layout for the partial implementation of the West Ballina Flood Relief

Table 2 Specification for the partial implementation of the West Ballina Flood Relief

	Minimum requirements	
	For mitigation of Lot1 DP238009 development	Ultimate West Ballina Flood Relief arrangement
Upstream floodway width	Min. 40m	
Upstream floodway invert	Natural ground - approx.1.0m AHD (can be excavated to ultimate level of 0.6m AHD for full 40m width or partial width as a low flow channel)	0.6m AHD
Access road culverts	Cells of 3.6m wide by 1.5m high	Up to 10 cells of 3.6m wide by 1.5m high
Access road culvert invert	Max. 0.5m AHD	
Access road culvert soffit	Min. 2.0m AHD	
Width of floodway between access road and River Street culverts	Min. 40m	Min. 40m
Invert of floodway between access road and River Street culverts	Constant grade from access road culvert invert to River Street culvert invert	
River Street culverts	2 cells of 3.6m wide by 1.2m high	Up to 10 cells of 3.6m wide by 1.2m high
River Street culvert invert	0.0m AHD	
River Street culvert floodgates	Floodgates to downstream side	
Slopes for all batters	Minimum to satisfy safety and maintenance	

Should you require any additional information or wish to discuss the contents of this letter, please feel free to contact the undersigned on 07 3831 6744.

Yours faithfully

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BMT WBM Pty Ltd

Ben Caddis

Associate, Senior Flood Engineer

cc Toong Chin (NSW Office of Environment and Heritage)

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